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Contents

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Manuscripts are to be submitted to associate editors of the appropriate section and *may* be submitted directly to the editor in chief. Clear manuscript, preferably typed, with wide margin to the left, with double spacing between lines, is desirable. Please try to follow the typographical style of the most recent issue of the Bulletin. Line drawings should be submitted on Bristol board, or similar material, and done in India ink. Figure number should be written on this in pencil. Titles for drawings, with figure numbers, should be typed on a separate sheet. Please try to minimize footnotes. Appended references and bibliographies, clearly so marked, should be done in the style of the A.A.A.S. publication, *Science.*

Science and Philosophy

SCIENCE AND CREATION

REV. JOSEPH P. KELLY, S.J.

As we are well aware, there appear from time to time in our newspapers and periodicals, feature articles on topics relating to science and philosophy. Recently, the problem of Creation has caused some discussion. Whether this means creation in the strict sense—production from nothing—is not quite clear. The question is not a new one. Back in the ancient days of philosophy, men of genius tried to find a solution of this cosmic problem. Lacking any influence of revelation, the Greeks were compelled to fall back on the eternal existence of matter. They could not understand a production of the world, or the production of anything, without a previously existing matter. From the principle: *ex nihilo, nihil fit,* they concluded to the eternal existence of the universe. The conclusion was in harmony with their experience.

The history of science tells us that many scientists, in the infancy of science, considered this question. Among them, Galileo, Newton, Boyle and others believed in creation in the strict sense, but on religious grounds and not on scientific evidence. Newton, in his famous *General Scholium,*[1] professes the creation of the world by God. Boyle declares that "God not only made the world in the beginning but His general concourse is continually needed to keep it in being and at work."[2]

In later times, the growth of science and its success in finding a natural explanation for phenomena led men away from the metaphysical and the religious aspect of the world. Locke and Hume proclaimed the separation of science from religion and argued that science should not be brought in for the support of religious doctrine. Hume's repeated attacks on miracles, as contrary to the laws of nature, and therefore impossible, is well known.

In continental Europe, similar trends of thought occurred. The rise of Positivism, the satires of Voltaire on religious topics, and the attacks of the Encyclopedists weakened to a high degree the religious outlook of men. All this tended to destroy the ties which in earlier years bound science with religion. In the last century there was the complete separation of science from religion and philosophy.

The last few decades have witnessed a change from this extreme position and some voices are heard in favor of religious doctrine, with-

1 Newton, "Principia," p. 543, Univ. of Calif., 1934.

2 Quoted from Dampier, "History of Science," p. 152, Macm., N. Y., 1940.

out fear of ignominy. The old materialism has gone and scientists have acquired a freedom of speech in questions touching on religion and philosophy. There are indeed many who would still refuse a place to metaphysics in the scientific world but in face of an opposite trend, their number is decreasing. The cause of this new outlook and the reasons for the modification would be an interesting study. Planck in a recent work[3] makes a pertinent observation. In his young days he was caught up in the controversy between Boltzmann and Ostwald on the problem of Thermodynamics. He says: "This experience gave me also an opportunity to learn a fact—a remarkable one, in my opinion. A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it." Perhaps we have an analogy with religious and philosophical truths in relation to science. Be that as it may, let us examine the problem of the beginning of the world.

Philosophical Viewpoint

In Scholastic Philosophy we find many sound arguments for Creation, e.g. from the contingency of being. We live in a mutable universe, composed of material bodies, which by their nature are contingent since they are changeable. Hence, they are not necessary beings and whatever they possess, in being and in properties, they must have received from something outside of themselves. They could not confer on themselves their existence and must have received it from another. When we get back to the first existing beings, we must then have recourse to a Creator and a Creative act which brought them into existence, out of nothing.

Again, from the principle of causality: "whatever begins to be, must have an efficient cause," we have a similar argument. Experience shows us that material bodies do not produce themselves but depend on something else to make them exist. A desk needs a carpenter to form it, a house demands a builder to construct it. Atomic bombs don't just happen. Likewise, for all material bodies of the universe, we are forced to look for a First Cause, uncaused in itself, to account for the existence of the world. One will find a fuller development of these arguments in textbooks on Scholastic Philosophy.

The Scientific Outlook

The scientific approach to the problem is not unlike that of philosophy. The logical analysis of the question of Entropy, according to the Laws of Thermodynamics, leads us to the threshold of creation. The scientist looks at the world from various angles, past, present and future. He sees many activities in nature wherein there is an exchange of energy under different forms, e.g., heat energy is convert-

[3] Planck, "Scientific Biography," p. 33, Philosophical Library, N. Y., 1949.

ed into mechanical work and motion. In these processes, some of the energy is lost; not altogether lost, since this would violate the principle of the conservation of energy, but lost to future use. It becomes *unavailable* to us. This is implied in the "efficiency" of steam locomotives and Diesel engines. Some of the energy is consumed in overcoming friction and more of it is dissipated into the atmosphere. This cannot be recaptured. No scientist has as yet discovered the formula for reclaiming the vast amounts of energy radiated into the air. A fortune awaits this genius. So, we can say that the *available* energy is decreasing day by day; the "degradation of energy" is an increasing function. Looking into the future we are heading for that dismal, "heat-death," of which science speaks, that condition of universal equilibrium which precludes all exchanges of energy and consequently all work and motion, this according to established scientific laws.

More interesting and more pertinent to our discussion is the review of the past, from this same point of view. For, as we travel over the years, or centuries, we see that the energy of the world has been *more and more available* until we finally arrive at a moment in which the energy of universe was in a *state of maximum availability*, or the state of *maximum organization* of energy. This is the "beginning"; this is the starting point of scientific investigation. We have reached the barrier beyond which no scientist may go, according to his principles and methods as a scientist. Science here reaches its limits. What then? What response can be made to the inquiring human mind which asks: "What happened before this?" "How did the universe come to be in this state of maximum energy-organization?" The agnostic scientist of the last century would perhaps reply with DuBois-Reymond, "We don't know; we cannot know." And some moderns would likely tell us: that is a meaningless question and has no answer.

On the other hand, there are many scientists of today who assume a very different attitude and are willing to face the logical consequences of their theories. They recognize the problem and see no answer in science. Says Eddington: "To go beyond the moment when matter and energy had its maximum possible organization, is scientifically impossible. We have come to another end of space-time, an abrupt end, only according to our orientation we call it 'the beginning'."[4] Here we are face to face with the problem of Creation, and this on scientific grounds or better on the logical analysis of scientific theory. To many scientists this will seem like an unwelcome outlook but there seems no way out of it. Since there is no answer in science we must turn to philosophy or revealed religion. But continuing along the same thought Eddington remarks: "Even those who would welcome a proof of the intervention of a Creator, will probably consider that a single winding-up at some distant epoch is not really the kind of relation between God and His world that brings

[4] Eddington, "New Pathways in Science," p. 58, Macm., N. Y., 1935.

satisfaction to the mind. But I can see no escape from the dilemma. One cannot say definitely that future developments of science will provide an escape."[5]

This notion of creation as a "winding-up" of the universe is but a scientific anthropomorphism, generated by the nineteenth century concept of the universe as a huge machine. It is indeed a very inadequate mode of expressing the real, philosophical concept of creation, the production of something from nothing, i.e., without preexisting matter. One can readily understand Eddington's repugnance to an "abrupt beginning," from a scientific point of view. The orderly sequence of events, from antecedent to consequent, the regular occurrences in nature according to the laws of nature, are part and parcel of the scientific mentality. Creation breaks the sequence. Yet, to postulate an eternal existence of the world and an "eternal sequence" is equally repugnant since it contradicts scientific principles. A finite universe with a finite amount of energy is not compatible with an eternal series of events in an infinite world.

Jeans also takes up the question and sees the same barrier to the investigations of science.[6] In earlier works, he speaks of creation in a strict sense, as an act wherein "matter which had not previously existed came or was brought into existence." He believes that the state of "maximum-organization" excludes the eternal existence of the universe and we are compelled to place some limit to the duration of the world, calculated to be about two million years. Again we meet the abrupt beginning and are on the frontiers of philosophy. Another analysis of this problem, made by Sir Edmund Whittaker, reaches the same conclusion. The irreversible processes in nature show the impossibility of completely recovering and restoring the energy of any system. "This is known as the Law of Degradation of Energy: the total amount of energy in the universe does not change, but it is always suffering degradation and can never climb back to its original state."[7] A critical appreciation of these facts leads us to the abrupt beginning of creation.

Planck also indicates this tendency toward a beginning through the Laws of Thermodynamics, although he does not explicitly mention the question of creation. His discussion of the relations between science and religion and between science and philosophy tends to the same logical outcome as held by the others.[8]

Other Methods

The consideration of thermal processes and the Law of Degradation of Energy is not the only avenue of thought that leads to a "beginning" or as one author has stated it—to Time: zero. The spontaneous

[5] Eddington, op. cit., p. 59.
[6] Jeans, "The Universe Around Us," p. 324, Macm., N. Y., 1935.
[7] Whittaker, "The Beginning and the End," Ch. II, Oxford, 1942.
[8] Planck, "Scientific Biography," passim, Phil. Lib., N. Y., 1949.

disintegration of radioactive substances and their gradual transformation from, e.g., Uranium to Lead, offers a similar picture of the trend from "organization to disorganization." The observed trend is toward disintegration. Reversing mentally this process we eventually arrive at the moment of total organization (Time: zero), when the phenomenon began. Here again we are the limits of investigation, marked off by the principles and methods of the physical sciences. Whence this organization?

The natural sequence of events and the order of nature in the long chain of natural causation has been a very important factor in the development of theoretical as well as experimental physics. We know how, according to LaPlace's Determination, the whole universe would be an open book to the scientist if he had the knowledge of the elements which constitute the sequence (the beings in sequence). Most present-day men of science would accord to this no more than a statistical value. Following our methods of extrapolation, as we trace this sequence farther and farther into the dim past, we arrive at this point: Either we accept with the ancients an eternal sequence of events, an infinite series, or we must stop at an "abrupt beginning," the starting point of the sequence. There seems to be no other alternative, theoretically speaking. I believe that few of any scientists would accept the first and so, we are compelled to accept the second on logical grounds. The limited sequence must have had a beginning, a creation, such as Eddington and Whittaker hold.

Today, some men of science are working on the theory that there is a "creation" of matter or better a re-formation of energy particles in outer space to compensate for the continual loss of available energy. Thus far, there seems to be too little certain knowledge of this process and the many difficulties in the theory do not permit a very definite judgment on the matter. Even if the theory proves to be valid, there still remains the question of the *first organization* of matter and energy and again we are on the frontiers of science and philosophy, or face to face with the question of creation, in the beginning.

Conclusion

The problem offers many angles and so many conclusions might be drawn from this discussion. It is quite obvious that the scientific mentality has changed profoundly in the past half century, with respect to philosophy. It is one aspect of what Bridgman calls the "intellectual crisis forced on the physicist by experimental facts hitherto unsuspected." It is equally clear from the history of scientific thought that discussions of this type would not have been admitted before the turn of the century. They would have been called "unscientific," not merely in the sense of being outside the realm of the natural sciences, but as being invalid. The modern scientist has abandoned that attitude, for the most part. He recognizes the limitations of science and of the knowledge derived through scientific principles

and methodology. He admits that other fields of knowledge have their value and are part of that hierarchy which constitutes human knowledge.

Out of Quantum Physics has come the idea of "complementarity," viz., that a phenomenon may not find an adequate explanation in one theory but may find its "complement" in another. For example, light phenomena may be inadequately explained either by a wave theory or by a corpuscle theory. A combination of the two may well furnish a satisfactory explanation of such phenomena. This sharing of the two theories gives rise to the notion of "complementarity." DeBroglie suggests that this concept might be valid outside the realm of physics, especially in questions which lie in the borderland of science and philosophy. We might say that the "beginning" of the universe finds a more satisfactory answer in a scientific extrapolation via the Laws of Thermodynamics, and a supplement from the doctrine of Creation. The "abrupt beginning" does not look so harsh when the two points of view are combined. Many other problems might find their solution in similar "complementarities."

Reviews and Abstracts

RECRYSTALLIZATION OF BENZOYL PEROXIDE **A WARNING.** *Organic Syntheses* Coll. Vol. I., 432 (1941). A paste-in page to go opposite p. 432 was issued with the twenty-ninth volume of this work. The original reference suggests *hot* chloroform for this recrystallization. Several severe explosions have been reported. Amended procedure calls for recrystallization from chloroform at *room temperature* by the addition of methanol according to J. Am. Chem Soc., 68, 1686 (1946). Lucidol Corporation in Buffalo supplies a recrystallized grade of Benzoyl Peroxide. *B. A. Fiekers, S.J.*

RESEARCH PAYS ITS OWN WAY by H. L. Russell (Alumni Rsch. Found., Wisconsin), *Sci. Counselor*, 6, 29 (1940). Develops university patent policy at Wisconsin. *Ed.*

SCIENCE VENTURES INTO PHILOSOPHY by Rev. Joseph P. Kelly, S.J. (Weston and *This Association,* Thought, 24, 598-616 (1949).

(*Continued on page* 93)

Biology

SENESCENCE AND DEATH

William D. Sullivan, S.J.

Senility, among the Greeks, was considered to be a gradual loss of innate heat. Up to the age of manhood, heat was built up and stored in the system. It was then gradually exhausted until, in the old man, it was completely burnt out, leaving the man a corpse. Aristotle, Hypocrates and Heraclitus emphasized the loss of heat as the cause of death. Cicero thought senescence to be an incurable disease. Even as late as 1732, Heuttner considered age a disease which could be cured if only the right apothecary were to be found who would prepare the serum of immortality. Fravorn, an eminent biologist of a few centuries ago, claimed that man was changing and passing through a "spontaneous crisis". To him "old age is merely the last stage in this evolutionary process. It is a natural phase of uninterrupted development beginning with the fertilized egg and ending with death."

In discussing senescence and death, two aspects of the subject must be distinguished: first, the aging and death of the individual cells of the organism, and second, the senescence and death of the entire organism itself. Obviously the two are intimately connected, for the age and death of the individual cells, especially those of vital importance to the organism, such as the nerve cells, eventually cause senescence and death of the entire organism. However, it is also true that while the entire organism may age, some cells within the organism are continually being replaced by new cells. In the case of the single cell animals, the protozoa, there is, of course, no distinction between the death of the cell and the death of the organism. From the very beginning of their development, some embryonic cells undergo senescence and death, so that in certain organisms there is a sheet of dead cells covering the entire animal. Again, even after the death of the organism, there are some cells which continue their activity, e.g. the amoeboid cells (leucocytes); the ciliary cells within the frog's gullet, which continue to manifest activity long after they have been removed from the frog itself (Sullivan, 1949).

When the individual cell undergoes senescence, there is a number of changes which take place within the cell. All these changes come under the one heading, *cytomorphosis*. One change stands out, perhaps, more than any of the others and is today receiving a great deal of attention in the laboratory; it is the pigment called *exhaustion*. This pigment seems to accumulate with senility, though its actual source is not too well known. It is believed that the greater the diffi-

culty in excreting unfavorable substances, so much the more pronounced will be the pigment. It is present to a much greater extent in the cells of the nervous system, than in the cells of the kidney or the liver. Nevertheless, the fact that it is a constant factor in all aging cells brings it to the front in investigation. The accumulation of fat droplets within the cell is another factor accompanying cytomorphosis. In the striated muscles it is disputed whether hypotrophy in aging cells is due to senescence or to the lack of activity; hypotrophy being a third common factor in aging cells.

According to their method of undergoing senescence and death, cells are divided into two types: (1) "labile" cells which undergo senescence and death and replacement very rapidly; (2) "stable" cells which undergo senescence and death gradually. Depending on the tissue in which the labile cells are found various degrees of change are noted. For example, the cells of the sebaceous tissue disintegrate completely and become part of the glandular secretion. In the stable tissue, there may be either a liquification of the protoplasm or a gelation of the protoplasm, both of which lead to the destruction of the cell. The diversified manifestations of senile changes in cells of different tissues make a general description of senescence and death almost impossible. It is necessary to make a detailed histological, as well as cytological, study of the individual organs from the embryonic stage to the adult stage and then to the death of the organism. The characteristic cytomorphosis of each individual organ must be examined.

Protozoa are continually dividing and reproducing through binary fission. According to Weismann the amoeba and the paramecium are truly "immortal"; mortality occurs only in the metazoa. The division of the amoeba and of the paramecium into two individuals of their species cannot be rightly said to end with the death of the first: "This process cannot be truly called death. Where is the dead body? What is it that dies? Nothing dies; the body of the animal only divides into two perfectly similar parts, possessing the same constitution" (1891). In view of Weismann's theory, Woodruff began a culture of paramecium in 1907, and by 1932, 15,000 generations had been produced and the cultures were as healthy as ever. No conjugation was allowed in these cultures. In the case of amoebae and peromyxae, authors say that they also can reproduce indefinitely without sexual intercourse of any kind (Johnson, 1930; Halsey, 1936). As opposed to Weismann's theory that immortality is to be found in the protozoa only, Child (1915) points out that "the problems of death and length of life find no solution in these speculations . . . it is not true that all multicellular forms necessarily die. As I have endeavored to show, many forms, both plants and animals, may escape death by reproduction and rejuvenescence in exactly the same way as do the protozoa". As a matter of fact some of the metazoa do undergo binary fission similar to the protozoa, i.e., the flatworm,

Planaria dorotocephala. Should the planaria be fed just enough to keep it alive, the animal becomes smaller in size, but lives a much longer life than the well-fed planaria. Starvation, then, seems to hold off senility in this animal at least. The reason is that starvation probably allows less metabolic poisonings in the system. The oxygen consumption per unit of tissue is actually decreased throughout the life of the planaria. With age this invertebrate flatworm increases in size and decreases in the oxygen consumption. If the size is reduced, therefore, by starvation, there seems to be a regain of oxygen consumption. Therefore, if the protozoa are to be classified as "immortal", at least some of the metazoa deserve the title as well. It is to be noted that in the more recent literature on this subject, the authors use the terms "potentially immortal". By this they mean to say that in cells which are continually dividing, there is present a chemical or physical replacement of cell protoplasm which stays off old age and death.

This whole subject of senescence and death has stimulated the research technique of very few biologists or even doctors until the present day. The subject of pathological agents in the cell is a subject studied with a great deal more enthusiasm. However, we shall see very shortly that brand-new subject of old age, called Geriatrics.

Man has often been compared to a machine, and like the machine has a tendency to outlive his usefulness and eventually wear out. The aging process of an automobile can be retarded by the removal of undesirable carbon or other waste deposits of oil and gasoline, as well as by the renewal of worn parts. The human body has its undesirable deposits of carbon and other substances, and, though these deposits may be excreted for the most part, there are some which the living organism has no means of removing. It may be the accumulation of these prducts, of which the aging body cannot rid itself, that is the cause of the death of the body. And it must be kept in mind that protoplasm can replace itself. This is perhaps nowhere better exemplified than in the case of the protozoa, mentioned above, which undergo binary fission.

In general, all animals and plants live for a definite span of days, months, and years and then die. When a man grows old many changes take place in his physiological and anatomical systems, eventually causing his death. There is a generalized calcification, especially of the rib cartileges. The bones become more brittle and in the case of breakage or fracture they heal more slowly. Such a condition of the bones is probably due to arteriosclerosis, poor nutrition or circulation. Deposits of calcium salts are increased in the arterial walls, decreasing the elasticity of these vessels (Cowdy, 1933; Winternitz and Le Compte, 1938). According to one authority (Minot, 1908), "longevity is a vascular question, and has been well expressed in the axiom that a man is as old as his arteries." The lens of the eye becomes cloudy and there is a general loss of the youthful acute sensitivity of all the senses. The senses most affected are vision and hearing.

The peculiar effect of old age on hearing is a defective sensitiveness to the higher tones, followed gradually by a defective sensitiveness to the lower tones. The focussing power of the eyes is reduced and sometimes lost altogether. This is probably due to the defective feeding of the blood supply to the retina, or to the muscular decay of the eye muscles. The gums weaken and the teeth fall out. The decay of the teeth is probably due to poor nutrition. The hair becomes gray and then white and the hair line recedes. The loss of hair can be attributable to many factors, heredity, diet, disease and vascular difficulties. Strangely enough there is an increase in the growth of the eye-brows, nasal and oral hairs. These abnormal growths suggest the complexity of the mechanism within the aging. The stamina and vigor of youth slowly fade away. Wrinkles and decoloration mar the face and the hands and the body in general. There is a decrease in the height of the individual and various organs of the system begin to atrophy, i.e. begin to wither and cease growing. There is also a decrease in the weight of the internal organs, the kidneys, the lungs, the liver and even the brain (Demange, 1886; Rossle, 1923; Donaldson, 1895). For example, the average weight of the liver of man at sixty years is 1,278 gms., while at ninety, it is 825 gms. Except for this decrease in weight no other sign of impairment has been noted in the liver of man. The normal weight of the kidney is 170 gms.; for those men of seventy years, it is 103 gms.; the average weight of the brain in man between twenty and forty years is 1,409 gms. and in man between the ages of forty-one and seventy it is 1,363 gms. There is a notable decrease in the weight of the lungs from youth to old age. The accumulation of non-living material in the human system results in the diminution of the amount of protoplasm in the system.

The rate of metabolism in the smaller animals is much higher than that of the larger animals (Brody, 1937). Actually the heart of the mouse beats at about 600 to 700 times a minute, while the elephant's heart pounds away at about 27 beats a minute. Physiologically, the two animals have an equal life span, even though the mouse lives for only three years and the elephant for about seventy years. Heilbrunn, as a point of erudition, points out that if the mouse lives for three and one-quarter years, its heart beats 1,110,000,000 times; the heart of the elephant during an average life time of seventy years beats 1,012,000,000 times (1943). Since animals differ in many other respects, these figures cannot be taken as an adequate criterion of the different lengths of the animal lives. Nevertheless, it can be an indication (and Heilbrunn says a "certain criterion") that animals which live a more active life meet an earlier death. Weismann, on the other hand, says that even though we may admit of some truth in all these speculations, it would be a great mistake to assume that activity necessarily implies a short life, and as proof of this he cites the cases of those active birds which have a long life (1891).

Measurements of all kinds have been made on the respiratory rates of old people in comparison with the rates in younger people: there is a progressive decrease in the rate of respiration as the individual ages (Benedict and Meyer, 1932; Benedict and Root, 1934). For most animals there is a lowering in the rate of metabolism as the animals advance in age (Benedict and Sherman, 1937; Black and Murlin, 1939; Deighton, 1923; Kunde and Nordlund, 1927; Pearse, 1936). The metabolism of man, however, is continuous at the same rate throughout life. This may be due to the fact that as man grows older he exercises less and less and so accumulates a reserve supply of fat. This will explain why even after the growth of his body has ceased there is no drop in the metabolic rate.

The digestive system also undergoes a complicated change of activity. The salivary glands do not produce as rapidly as in youth. The acidity of the gastric juices is weakened; ptyalin, the glycogen dissolving enzyme in animal cells, is lessened. The lack of proper nutritional habits in the middle-aged and beyond middle-age often causes an individual to appear much older than he actually is.

In the endocrine systems the testes have a longer life span than that of the ovaries. The hormone production involved in the libido and copulation mechanism seems to deteriorate sooner than does the actual production of the spermatozoa.

With the process of aging there is an increased pigmentation in the exposed parts of the skin, a decrease in the water content, fatty substances, and elasticity of the skin. Due to the decrease of the sebaceous gland activity there results a definite dryness of the skin.

Though it cannot be said that there exists a disease peculiar to old age alone, however, there are certain diseases which are more prevalent among the aged. These diseases are, no doubt, due to the deterioration of the different immunitive activities within the human system. Some of these diseases are, in the order of appearance as the organism progresses beyond maturity, circulatory and renal diseases, diseases of the metabolic processes, arthritic ailments and cancer.

Geriatrics, the so-called step-child of medicine, is relatively a new field of investigation into the medical care of the aged. Since aging begins, strictly speaking, with conception and ends only with death, the study of geriatrics is, perhaps, the most wide-open field of endeavor. It must include not only the pathological effects on the organism, but the health of the organism as well. Every subdivision of medicine and biology to say nothing of the physical and chemical study of the human organism, must be considered. Since it is a study so new, about all that geriatricists know to date is that man grows old. Heredity plays a very important role in the life span of an individual. The geriatricists have observed a gradual destruction of various tissues, a decrease in the elasticity, especially in the connective tissues, and a gradual decrease in the repair of wounded tissue, which is due to the decrease in cell division and growth. Though the

tissues may heal satisfactorally, they do so much more slowly. One geriatricist has said, "It is practical and justified to assume that for each five years of life an additional twenty-four hours are required for repair."

So far we have seen many, but not all, of the changes that man undergoes as he advances in age. According to Heilbrunn, "there has been no lack of theory" to explain the changes themselves (1943). These changes were first attributed to poisonous substances produced in the digestive tract by putrifactive bacteria (Metschnikoff, 1903; 1910). However, by the cultivating of fruit flies, one in a sterile medium, another in a bacterial medium, it was shown that such was not the case. The flies reared in the sterile culture lived no longer than those in the contaminated one (Pearl, Park and Miner, 1941). Another theory proposed was that of the reproductive cycle. Some animals reproduce only once and then die. Experiments performed on other animals which reproduce more than once produced some amazing results. The cutting of the vas deferens in senile rats resulted in a life span longer than that of rats on whom no operation was performed (Steinach, 1920). Many of the authors disagree with the theory based on this experiment (Romeis, 1921; Oslund, 1924). Heilbrunn says, "Although it may well be possible that the secretions of the glandular cells of the testis have some effects on muscular vigor or sexual appetite, the secretions of the testis can have little effect on the aging process, as is evidenced by the fact that castrated animals grow old quite in the same manner as normal animals." Insufficient diet may prolong the lives of some animals (Northrop, 1917). The Planaria has already been cited as an example of this. Also there are certain cells which deteriorate much more rapidly than others. If the latter are the more important cells in the animal, then death will come more quickly than if the less important cells first deteriorate. The cells of the brain cease to grow or increase in size or number soon after birth. Once these cells are destroyed there is no reproduction of new cells. According to some of the authors it is primarily the degeneration of the brain cells which causes the beginning of the whole process of aging and death (Andrew and Cardwell, 1940). Bernard Shaw is definitely incorrect when he says that the human body changes its cells every seven years. The brain cells which we possess at birth are the same cells, though less in number, which we carry to the grave. Whatever the true theory may be, it is quite definite that it is a protoplasmic change occurring in the individual cells which causes senescence and death. Aging, however, may be avoided in certain tissues by the repeated divisions of the cells there. It has also been known to happen that sections of tissue from the higher animals have been preserved alive in culture media outside the body of the animal. The first experiments performed on the culturing of cells outside the body were those of Harrison in 1907. Since his time a great deal of work has been done and the results show that a variety of cells, both adult and embryonic, can be preserved for a

long time in this manner. Many cells transplanted at the time of death can continue to live in another individual as hosts. The famous culture of cells from a fragment of chicken heart continues to grow after thirty-six years. Its cells need only the renewal of nutritive fluid to continue to live an apparently endless existence. On the other hand very well differentiated cells, such as those of the nervous tissue, generally lose the capacity to reproduce and hence the capacity to be cultivated in vitro, and so are condemned to senescence and death.

The inevitable result of senescence is death. Death to the biologist is the inactivity of all the cells within the organism. Pearl claims that the causes of death are due to a biological condition in at least 85 to 90 out of every 100 instances (1941). He lists the following in their descending order of importance. Defects of (a) the respiratory system, (b) the alimentary tract and the organs associated with this tract, (c) the circulatory system, (d) the nervous system and the sense organs in general, (e) the kidney and other related organs of excretion, (f) the primary and secondary sex organs, (g) the skeletal and musculatory systems, (h) the skin, (i) the endocrine system.

Embryologically, the proportion of the three layers of cells has been worked out, in regard to their capacity to cause death in the individual, to be: ectoderm to endoderm to mesoderm as 1 is to 3.8 to 5.2.

In death, breathing stops, and rigor mortis sets in. Rigor mortis is nothing more than the rigid contracture of the voluntary muscles. Cessation of breathing, however, does not mean that death has come to the body, for the lungs may still continue to draw in air without breathing. Stoppage of circulation is a rather definite sign of death. Though the motor nerves may continue to function after death for as long as one hour, the rest of the nervous system ceases to function. In laboratory animals which have been sacrificed, it has been found that certain of the nervous cells survive as long as 120 hours after death (Lewis and McCoy, 1922). It has often been said that the hair and nails continue to grow after death, but that is a debatable question. Even individual cells may continue to function after the death sentence has been passed by nature on an organism. Some of the enzymes within the cell may continue to perform their various functions, since they are not living, but are chemical catalysts, and neeed only the presence of the protoplasmic constituents, living or dead for their proper functioning. However, when all activity of every kind ceases, and only then, may the organism be said with certainty to be dead.

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(Continued from page 85)

A Simple Method for Welding Thermocouple: by J. A. Riley. *Science, 109,* 281 (1949). D. C. electrical method is used for iron constantin, platinum platinum-rhodium, chromel alumel and copper constantin couples. One pole is the couple; the other, a mercury pool under oil in a metal container (metal shell of a vacuum tube). Polarity is not clear. Current is important—so resistors are incorporated in series with 115 volt line. Technique is indicated; experimentation is recommended. *B. A. Fiekers, S.J.*

Theses on the Qualitative Analysis of Plastics by Dr. O. L. Baril (dir.), E. M. Di Geronimo et al. Experimental undergraduate theses available on Interlibrary Loan. 1943 to date. A schematic outline for the identification of common plastics appears in the first thesis in the binder. A number of theses over the period of subsequent years continue the idea and attempt to incorporate other plastics of

(Reviews and Abstracts continued on page 98)

Chemistry

CONDUCTIVITY EXPERIMENTS FOR FRESHMEN

Rev. Gerald F. Hutchinson, S.J.

Conductivity experiments are an important part of the first year chemistry course. An extremely simple apparatus can be arranged so that each student may perform as many tests as are desirable. Two ordinary screw-in sockets are connected in series to the electrical outlet. In one of them is screwed an ordinary bulb which will light with a conducting solution. A burned out bulb from which the glass has been removed is screwed into the other socket, and the assembly is arranged so that the electrodes extend in a downward direction. A test tube, containing the solution to be tested, can be slipped over the bared electrodes of the broken bulb. By dipping with distilled water between test solutions a great variety of substances can be quickly tested, and conductivity and non-conductivity, conditions required for conductivity and degrees of conductivity as well as other conditions quickly established.

Father Buck, S.J., arranged this apparatus at Fairfield.

CHEMISTRY LABORATORY HINTS

I. Agitation and Stirring

Rev. Bernard A. Fiekers, S.J.

Agitation, stirring or mere rotation in the growing of crystals from solution is not as simple a job as some might think. For, if the growing crystal is always rotated in the same direction, its edges become rounded and the purpose of the experiment is frustrated. The ideal would be to be able to reverse the direction of the rotation, after a small number of turns, for an exactly equal number in the opposite direction. Certain automobile valve-grinding devices, to be brought at reasonable price in almost any automotive accessory shop, can be of service here. The handle and the valve driver are dismantled from their respective shafts. The driving shaft is coupled to a variable speed electric stirring motor and the driven shaft, to the rod on which the crystal grows. The use of short lengths of pressure tubing for the couples has this advantage that the driving force is thus cushioned when its direction is changed, and the crystal is less apt to crack away from its supporting rod. One valve grinder used here rotates 360° in one direction for every 200° in the opposite. For some reason or other, we have not found that the bias is significant in the growing of large crystals.

Such a device is useful in the grinding of glass stoppers and

joints. Indeed, the use of it for this purpose by the late Father Aloysius B. Langguth, S.J., suggested the possibility of adapting it to crystal growth technique. The adaptation was made by student, James Van-Hook, at Holy Cross.

Familiar too, as an agitating device, is the automobile windshield wiper, also available from the same source, and an old familiar in the literature: *Anal. Ed., Ind. & Eng. Chem.*, 8, 62 (1936) and *Hormone*, 15, 11 (1942). A stiff piece of glass or brass tubing, mounted in a vertical direction, serves as a guide for the stirring rod, which is attached to the moving part of the wiper so that its motion will be vertically up and down. A loop on the extremity of the rod, bent into a horizontal plane, might provide sufficient paddle structure for most jobs. Suction from a water aspirator provides the power.

Perusal of the fifteen volume index of the *Analytic Edition* of *Industrial and Engineering Chemistry* reveals numerous entries on agitation and stirring. Electric, water and air motors are listed; there is magnetic stirring and the use of spiral electrodes in electrode-position analysis which causes the ionic solutions to swirl like a self-contained motor.

In experiments on kinetics in physical chemistry, where volumes of gases are to be measured, the use of mercury-sealed stirrers can be a source of error that is often overlooked and difficult to evaluate. The speed of stirring can change the height of the mercury level in the well by centrifuging the liquid against the walls, thus possibly changing the pressure on the system. The difficulty might be obviated by using constant speed where only the consistency of the data is necessary or by the substitution of mercury-less stirrers. *Hormone*, 5, 87 (1931). With some, the spillage of mercury is unforgetable and unpardonable, not only from the point of view of the errors involved in quantitative work, but from that of the health hazard of its vapors as well. Some recommend the use of a papier mache tray under all apparatus that contains mercury. Some laboratories are ventilated thoroughly after the week-end closing. The routine cleaning of sewage traps in some places sometimes yields pounds of the liquid. Prevention, detection and recovery are indicated. The stoppering of the sealed stirrer has been recommended to prevent spillage. *Hormone*, 6, 72 (1932). The vapor is detected by mercury vapor indicating lamps now on the market. One of our members has suggested the use of a silver device, which has been amalgamated on the surface in order to recover and collect small droplets of mercury which seems to be attracted by the amalgam; *J. Chem. Educ.*, 22, 463 (1945).

In order to avoid the use of the mercury-sealed stirrer consider the following. Cover the mouth of the flask with a wide nipple from a baby's milk bottle and pierce the nipple with a stirring rod that reaches down toward the bottom of the flask and also forms a tight joint with the rubber. The rod will not rotate on its own axis, but can be manipulated at the upper extremity so that its lower extremity

describes a circle around the bottom of the flask. It can be driven by a motor that has on its shaft a disc of convenient diameter, with a slot cut into it that will catch the upper extremity of the rod and rotate it in the manner described. Sturdier and more durable rubber joints can be tailored in the laboratory from latex, or cut from a rubber stopper in the following way.

Select a rubber stopper with a single hole to take the rod snugly.

Work the stopper flat on the bench with the great circle down; the smaller circle upwards. Cut a trench or moat that is concentric with the single hole and about twice the diameter of the rod. The rubber stock left around the hole should be about as thick as the diameter of the rod. The depth of the trench should be such that supporting stock is left, to again roughly the diameter of the rod. The rod is then inserted and adjusted. Short neck flasks should be used. The general idea may be found in *Anal. Ed., Ind. & Eng. Chem.*, 8, 488 (1936). For the stopper modification, the author acknowledges the idea of an earlier co-worker, Roscoe Smith.

(To be continued)

ELECTRONIC DEVICE FOR PRECISE TEMPERATURE REGULATION

Rev. Albert F. McGuinn, S.J.*

Many research problems require a water bath with temperature controlled within narrow limits over long periods of time. Having adopted mechanical agitation by compressed air as the best means of maintaining uniformity of temperature within the bath, Mr. John Kierstead, Technician, has developed a mechanism for delicate control of the heating element. In a bath of 15 liters capacity, the device has maintained constant temperature over long periods within $\pm 0.013°$ C.

The following advantages of the device may be noted:

1. It can be constructed from inexpensive parts. The cost for one unit is approximately $5.00.
2. It is extremely sensitive in response to the contact made by the mercury thermoregulator.
3. There is no fouling of the contacts because sparking is absolutely eliminated on the make and break of the regulator points.

We make no attempt to give theoretical explanations of the function of the various component parts, but we are ready to answer such inquiries.

The essential features of this device are best described by a wiring diagram (Figure I).

* John Kierstead, co-author.

In constructing the unit, only ordinary skill is required. Either stranded or solid #14 "push back" wire may be used. The mounting of the socket, condenser, and relay should be done first on top of the box type chassis. All the wiring is done beneath the chassis to insure protection against spillage of chemicals or handling. The power supply to the heating element should be asbestos covered electric-iron cord, with female rubber plug to which any heating element may be attached. Where the A.C. input cord and heating cord enter the chassis, rubber grommets are inserted. It is all important to pay attention to the polarity of the electrolytic condenser.

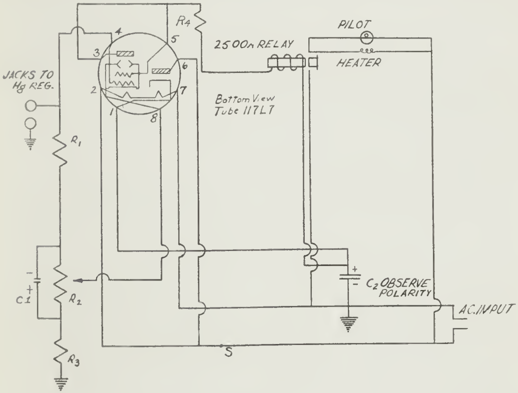

Figure I.

Components

1 Chassis—box type—aluminum—5×7×2
"Zip" cord for A.C. feed.
1 Plug—male—for A.C. feed.
1 Plug—female—for A.C. heater feed.
Asbestos covered electric-iron cord—required length.

Resistors

R1 = 12 megohms ½ W
R2 = 3000 ohms—variable—tapered wire wound—with knob to fit shaft.
R3 = 1500 ohms 2 W
R4 = 1200 ohms 2 W

Condensers

C1 = .01 mfd. 600 V.D.C.
C2 = 20 mfd. electrolytic, can type, D.C. W.V. 450

Switch

Bat handle—S.P.S.T. toggle and plate for "ON"-"OFF".

Tube

117 L7/GT

Pilot light

110 V Clear—with socket and jewel.

Relay

2500 ohm with S.P.S.T. or D.P.D.T. contacts, capable of handling about 7 amps.

Miscellaneous

Hook-up wire—about 4 feet
2 tip jacks and plugs for same
Flexible wire as needed to make contact with Hg regulator.

Operation

When the control is turned on, a few seconds will elapse before the relay closes. When the relay does close, the pilot light will show red, indicating that the circuit is correct and that the unit is ready for use. The heater should now be plugged into the female connector-outlet on the asbestos covered cord. The two leads from the tip jacks are touched together as a further check on the circuit. Upon touching each other these leads should cause the relay to open, extinguish the pilot light, and shut off the heater. In actual operation the pilot will be ON when the heater is ON.

The 3000 ohm variable resistor controls the grid sensitivity, and can be adjusted when a change in line voltage requires it. In the original installation it is turned clock-wise to the limit and the jack leads are touched together. The relay should open as stated. If the relay does not open, the resistor knob is turned counter clock wise until it does. If the relay chatters when turned on, simply reverse the plug in the line outlet.

(*Reviews and Abstracts continued from page* 93)
commerce into the scheme. The work is being continued. *B. A. Fiekers, S.J.*

Copper in Organic Chemistry by Gerard Kirsch. *Interchemical Review, 7,* 67-78 (1948). This is a survey of copper as reactant, catalyst and complex component in theoretical and applied organic chemistry. Portraits of Father Nieuwland, C.S.C. and Paul Sabatier are included. A bibliography of fifty references is appended. *B. A. Fiekers, S.J.*

(*Continued on page* 100)

Mathematics

APOLLONIUS AT ERLANGEN

Rev. Arthur Steele, S.J.

Mathematical history can be descriptive or problematic. A specimen study will help to mark the difference. Pappus' abstract of Apollonius' *Plane Loci* is translated by Thomas L. Heath[1] with the solitary comment that it be elementary and apparently confused. Let us examine the passage ourselves.

It is a highly articulated conditional sentence. Understanding by "segment" a segment of straight line, an articulated translation runs: "(1) if two segments are drawn (2) either from a single given point (3) or from two points and (4) either in a continued straight line (5) or parallel (6) or under a constant angle and if their lengths have (7) either a constant ratio (8) or a constant product, and if (9) one segment ends on a given straight line or circle, then (10) the other will end on a thereby determined straight line or circle, sometimes (11) the same species of curve and sometimes (12) the other species, sometimes (13) in similar posture towards a reference line, sometimes (14) in dissimilar posture."

Articles (1)-(8) link the FREE end of the first segment with the BOUND end of the other through a set of constant relations, so that Apollonius here propounds a number of geometrical FUNCTIONS or transformations. They include translation (3) or its absence (2) and rotation (6) or its absence (4-5) and dilatation (7) and circular inversion (8). To the modern geometer, mindful of Moebius, already a most intriguing collection. The treatise on *Plane Loci* is a study of the straight lines and circles in the plane. Articles (9-10) go on to assert that THESE curves are SETWISE invariant under THOSE transformations. We can pretermit the recognizable subtleties in (11-14) and yet ask pointedly, whether this really be "elementary but confused"?

Pappus' abstract enables us to seal off the ancient myth of a Plato who permitted only ruler and compasses. Aside from Plato's express acceptance of the solvability of a problem demonstrably beyond those instruments, aside from its solvability by curves and methods extant at that place and time, aside from other arguments, we now watch Apollonius, but a century later, erect the set of all straight lines and circles in the plane into an astonishingly organic totality of curves rather than any adventitious collection, and this in a spirit admirably fitted to develop into the "*Erlanger Programm*" of Felix Klein.[2]

Mountain masses appear simple from the valley floor, but reveal their true summits to an eye on the opposite ridge. So it is with Greek

mathematics. It rises here and there to heights which only modern abstract algebra can triangulate. So much is there, that a historian might easily be carried away by the dialectic momentum of the subject and see more than is warranted. Yet the mathematical historian is no less enured to this danger than to its perhaps greater opposite, the danger of trivialization. A treatise may surely exert strong, if delayed, influence through entailments outside the mind of its author. Even if the historian of a single period could be allowed to stress the descriptive at the expense of the problematic, the historian of several periods must be alert to every potential catalysis of a mathematical idea.

To such refinements as Euclid's perfect detection of the unique factorization lemma, that prime divisors of a product must divide at least one factor, or Eudoxus' perception and execution of the duty of proving a certain relation transitive, Heath is unfortunately impassive. He is a good Greek scholar, but in mathematical resonance he falls behind A. E. Taylor, not to mention the exact research embodied in *Quellen und Studien*. Since he is almost the only authority quoted for Greek mathematics by writers in the English language, a short but not disrespectful note of caution seemed proper to be sounded. Do not use him for negative arguments.

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1. Heath, Thomas Little: "A History of Greek Mathematics." Oxford I-II, 1921. See for Apollonius' Plane Loci: volume II, page 186.
2. Klein, Felix: "Vergleichende Betrachtungen ueber neuere geometrische Forschungen," Erlangen 1872; Gesammelte Abhandlungen 1 (1921) 460-497.

(*Reviews and Abstracts continued from page* 98)

A Simple Bridge Balance Indicator for Conductance Measurements by E. B. Thomas and R. J. Nook of John Carroll University, Cleveland, Ohio. J. Chem. Educ., *27,* 25-26 (1950).

Ultrasonics—New Research Tool by M. J. Monahan, American-Marietta Company, *Paint, Oil, & Chem. Rev., 112,* 19 (1949). Article based on an address delivered before the students of the North Dakota Agricultural College. Contains a review, intentionally not critical in nature, of commercially available ultrasonorators available in supply today. Piezo-crystal and mechanical models are emphasized; magneto striction not mentioned; large scale industrial applications are noted. Short bibliography appended. *B. A. Fiekers, S.J.*

Physics

THE THERMISTOR IN DIFFERENTIAL THERMOMETRY*

Edward J. Kilmartin, S.J.

Although the free surface energy of crystalline solids has been discussed for a long time by physicists and chemists from a theoretical point of view, up until recently little actual experimental data has been obtained in support of the theoretical calculations. Many research institutions are interested in the problem, including for example the University of Chicago.

The lack of suitable temperature-measuring devices seems to the author to have provided to some extent a bottle-neck to the determination of data in this field. Further, instruments for the determination of small temperature changes have in general been costly and out of the reach of smaller laboratories. Within the last fifteen years, however, thermally sensitive resistors have been developed to meet the need. They are low in price, easy to operate and they possess the desired efficiency for measuring temperature changes of small magnitude.

Although the *Thermistor* may seem at first sight to be a very delicate tool, a well-aged thermistor, used in temperature measurements was found to agree with its calibration data within 0.01° C., after two months use at various temperatures up to 100° C.[1] In connection with research work being carried on in the Department of Chemistry at the College of the Holy Cross, we have had occasion to use a thermistor in measuring the surface energy of crystals of about 3×10^{-4} cm. radius. Measurements were taken in a calorimeter. Since the temperature changes caused by the surface energy of the crystals, on introduction to a saturated solution, were small, a Bell Laboratory thermistor of no. 2 material, composed of the oxides of manganese, nickel and cobalt, had to be employed. The cold resistance of this thermistor flake is about 300,000 ohms at 25° C. It undergoes a change of approximately 4% resistance per degree Centigrade. A Wheatstone bridge with sensitive galvanometer was selected for measuring the resistance. Since the resistance changes about 12,000 ohms per degree Centigrade, a 100 ohm change corresponds to 0.008°C. With galvanometer sensitivity at 2×10^{-10} amperes per millimeter, per meter, a temperature change of 0.0005° C. has been

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*Preliminary report on apparatus used in thesis in partial fulfillment of requirements for the Master of Science Degree (in Chemistry), College of the Holy Cross, Worcester 3, Mass.

[1]Becker, J. A., Green, C. B., and Pearson, G. L., "Properties and use of thermistors, thermally sensitive resistors," *Elec. Engineering*, p. 25, Nov. 1946.

obtained with ease according to a Bell Laboratory report.[2] We have not realized such sensitivity, due to the galvanometer we employed; 0.005° changes were, however, observed by us. The flake of the thermistor used is 10 mm. thick with an active area of 0.5 mm. squared.

To measure heats of solution or heats of wetting the thermistor is placed in a thin-walled glass tube, just wide enough to allow for passing the thermistor down its length. The extremity of the tube is blown thin. Copper wires pass down the tube to the leads of the thermistor, and the top of the tube is sealed in a suitable way, so that the unit may be immersed in the solution in the thermostat. With this arrangement the thermistor will react in a matter of one or two seconds. This is quite an improvement over the Beckmann type of thermometer with its great time lag due to the heat capacity of the mercury well.

The thermistor we have described is extraordinary for its high resistance and extreme sensitivity. There are however, many other types, to be used in ordinary work, such as the following from the Western Electric Company. Type D 170575 with a 0.015 flake and a one second reaction time in still air, and type 14 B, glass-enclosed, with a 0.1 in. diameter flake at the end of a 2-inch glass stem and a reaction time of 25 sec. in air and 2 sec. in water, might prove attractive for routine thermometry. Both have 2000 ohms resistance at 25° C. and temperature coefficients greater than 3% per degree Centigrade. They cost about $1.50.[3] The Western Electric Co. has a number of thermistors whose cold resistances at 25° C. vary from 250 to 380,000 ohms. The General Electric Company is also in the field with somewhat less variety to offer. The appended references might prove to be of value.

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4. Roloff, C. C., "Thermo-variable resistors," *Electrical Review (London)*, February, 1947.
5. Zeffert, B. M., and Hormats, S., "Application of thermistors to cryoscopy," *Analytical Chemistry, 22,* 1420 (1949).

[2] ibid., page 27.

[3] Private Communication: J. E. Bigelow.

CURRENT NUCLEAR PHYSICS. PART IV.*

WILLIAM G. GUINDON, S.J.

II. ISOTOPES (*continued*)

3. Nuclear Systematics

a. Correlations of Observations

One of the clearest indications of system among the varied properties of nuclei is found in the general appearance of the isotope chart. Not every possible combination of neutrons and protons forms a nuclear species found in nature or producible in the laboratory. Investigation of the relative abundances of natural nuclei shows that isotopes with certain "magic" numbers of neutrons or protons are more abundant; presumably these combinations of neutrons and protons are more stable than others, an assumption confirmed by the fact that these same isotopes possess other characteristics indicative of greater stability (1). Correlation of isotopes by their radiations is another systematization free of complicated hypotheses; the limits of stability against beta-decay have been discussed (2), and the systematics of the heavy alpha-emitters delineated (3). The few remaining studies in correlation confirm a notable exception to the empirical rules for the spin of nuclei containing the same number of protons and neutrons (4), and calculate the radii of light nuclei from bombardment data (5).

b. Theories

In addition to a few suggestions that seem to be somewhat *a priori* in character (6), two attempts to explain the observed regularities of the isotopes are worthy of note. The first links the observed relative abundances of nuclei with their neutron-capture cross-sections. In this theory, the universe initially consisted of very dense radiation with a trace of neutrons. As this gaseous mass expanded, neutrons decayed into protons which captured other neutrons, forming deuterons, the deuterons in turn captured neutrons, etc. Ultimately the whole system of isotopes was formed by competition between neutron-capture and beta-decay until the progress of the expansion of the universe made further neutron-accretion impossible. Despite the provisional state of the calculations, this theory gives a good prediction of experimental abundances, and at the same time agrees with other cosmological data (7). Since this theory demands a process that is arrested by the changing condition of the universe rather than by the attaining of equilibrium, it differs from attempts to explain abundances by nuclear reactions at thermal equilibrium (8). The second attempt at systematization proposes a classical model: the nucleus is visualized as a crystalline arrangement of neutrons and protons; this

* This is the final part. Earlier installments are: Part I, THIS BULLETIN, 25, 95 (1947); Part II, ibid., 26, 58 (1948); and Part III, ibid., 27, 23 (1949).

model seems to fit relative abundances, the charge/mass ratios of fission products, and the asymmetry of fission itself (9).

III. Fundamental Interactions

1. Simple Systems

a. Scattering Experiments

Experimental observation of collisions between fundamental particles provides the basis for the theory of nuclear forces, hence the importance of such observation cannot be overestimated. Foremost among such scattering experiments are those studying the collision of neutrons with protons; the electrically neutral character of the neutron prevents the obscuring effect of Coulomb repulsion, present when both target and projectile are charged, and ensures that the scattering is due to purely nuclear forces. The scattering cross-section (total probability of being deflected) and the angular dependence (probability of being deflected by a certain angle) for neutron-proton scattering has been measured both for very slow neutrons and for those with energies from 2 to 15 million electron-volts (10). Other measurements of very low energy neutrons scattered by crystals and in ortho- and para-hydrogen show that the range of the neutron-proton force is only about 1.5×10^{-13} cm, very much smaller than hitherto supposed (11). At the other end of the energy scale come the early experiments with 100 million electron-volt neutrons: the results indicate that the neutron-proton force is a mixture of ordinary and exchange forces in comparable amounts. Exchange forces are so called because the proton delivers its electrical charge to the neutron during the collision, and thus the roles of the neutron and the proton are exchanged (12).

Proton-proton scattering is the simplest type of nuclear collision involving charged projectiles; angular distributions of scattered protons and total scattering cross-sections have been measured for a variety of energies from 2 to 15 million electron-volts (13). Other scattering experiments employed deuterons as target nuclei and either neutrons (14) or protons (15) for the projectiles.

b. Scattering Theory

A few papers concerned themselves with general aspects of scattering experiments and their use in manifesting the nature of nuclear forces (16). Many more contributed analyses of the various experimental researches or developed new theories for comparison with experiment. Naturally, as in the experimental papers, neutron-proton scattering received most of the attention. The object of one set of studies was the scattering of slow neutrons by bound protons (17). Another group of papers discussed the range-correction to the simple scattering formula (18). Several analyzed the dependence of the computed cross-section on the theoretical assumptions concerning the shape of the neutron-proton potential function (19). A theoretical

discussion of the ortho- and para-hydrogen scattering of neutrons is given, from which the range of the neutron-proton force may be determined (20). A large class of investigations was interested in the scattering of neutrons with energies of 100 million volts and up, a theoretical reflection of the recent appearance of instruments making such experiments possible (21). As yet none of these theoretical suggestions gives a completely satisfactory explanation of experiment, so that the need for radically new theories is highlighted.

Papers analyzing proton-proton scattering at a variety of energies interpreted the results in terms of familiar potential models (22). A few studies sought for new methods of analysis, including the effect of adding small potentials of long range to the specifically nuclear interaction (23). A discussion of the results of the scattering of neutrons by deuterons took place: does the evidence favor the existence of exchange forces between nuclear particles? (24) The same question is asked of the experimental evidence on proton-deuteron collisions, and here the answer seems more surely to favor the affirmative position (25). The scattering of both neutrons and protons by deuteron targets at extremely high energies, in the range 100 to 200 million electron-volts, is explored in approximate theories (26).

c. Bound Systems

Besides the experiments and theory relating to scattering collisions between fundamental particles the properties of simple composite nuclei are of special importance for the construction of nuclear theory; here the nuclear forces succeed in binding the neutrons and protons together into a more or less stable configuration, the properties of which reveal the qualities of the forces themselves. Pertinent observations include measurements of the magnetic moments of the deuteron, of the triton, and of the nucleus of He^3 (27), and the determination of the binding energy of the deuteron (28). Attempts to fit theory to the observed properties of the deuteron employed ordinary and tensor forces with square-well and Gaussian potentials (29). The moderate success of these theories prompted their application to the calculation of the binding energy of the next simplest nucleus, the triton or nucleus of H^3 (30), and to the problem of the magnetic moment of H^3 and of the similar He^3 (31). The problem of the photo-disintegration of the deuteron by photons of energies up to several hundred million electron-volts also received some consideration (32). The theory of a much more complicated nucleus, that of Be^9, is also discussed, because certain simplifying assumptions can reduce the problem to a three-body one (33).

d. New Phenomena

Here one must collect some very varied papers on new fundamental particles and new types of interactions. The most prominent of the problems considered is that of a force between the neutron and the electron. Some of the papers on this topic were experimental and

sought to measure the scattering of slow neutrons by electrons, with rather uncertain results (34). On the theoretical side, it was not so much a new interaction that was looked for, as the evaluation of the ordinary electromagnetic force between the magnetic moment of the neutron and the Coulomb field of the electron or nucleus (35). Other investigations attempted to detect the scattering of neutrinos by hydrogen (36), and rejected the hypothesis that anomalies in cloud-chamber studies of electron tracks indicated the existence of a low-mass neutral particle (37).

2. Relativity

a. Direct Applications

The direct correction of the formulation of nuclear interaction problems so as to satisfy relativistic considerations is a rather rare occurrence, as most of the interest in this matter centers about more thoroughgoing, general theories. The effect of using relativistic expressions for the computation of the magnetic moment of the deuteron is discussed and it is concluded that this effect is as yet not capable of being detected experimentally (38). On the other hand, bombardment apparatus has reached energies at which relativity affects nuclear particles; for such collision experiments the description of nuclear forces by static potentials breaks down, so that velocity-dependent forces may assume prominence (39). More inclusive studies have attempted to set up unified theories of the gravitational, electromagnetic, and vector-meson fields of force (40), but these are not without their proper difficulties. These researches represent a small, but significant, part of the broad field of advanced physical theory which includes the new advances in relativistic quantum electrodynamics and in the meson theories of nuclear forces, both of which will be mentioned briefly below.

b. Discrepancies from Dirac Theory

Under this rather general heading will be included three interrelated phenomena: the anomalous hyperfine-structure separations in the spectrum of hydrogen and deuterium, the Lamb-Retherford shift of some of the lines in the hydrogen spectrum, and the intrinsic (anomalous) magnetic moment of the electron. Strictly speaking, these three phenomena are not nuclear effects, but they are included here because of the impact of the theoretical explanations of these effects on advanced nuclear theories. This impact is seen more concretely in the obvious analogies that may be found in theories of nuclear phenomena, and also in the fact that a large amount of nuclear information comes from spectroscopy, which must be interpreted in a way that resolves these discrepancies.

The hyperfine structure of the line spectrum of an element is due to the spin and magnetic moment of the nucleus; the separation of these spectral lines can be calculated once the value of the magnetic moment of the nucleus is known. For H^1 and H^2, whose mo-

ments are known with great accuracy, this computed separation is about one quarter of one percent less than the observed separation, a discrepancy much greater than the probable error of the experiment (41). Several preliminary attempts to remove this discrepancy were brought forward, achieving some improvement by increasing the accuracy of the theoretical calculations (42). As will be seen later, advances in quantum electrodynamics were to resolve this difficulty as well as the following ones.

Discrepancies between theory and experiment were also discovered in the fine structure of the spectra of hydrogen and helium. In the case of hydrogen, two lines, which according to the Dirac relativistic theory of the electron should have the same frequency, were found by Lamb and Retherford, at Columbia, to differ by 1000 megacycles; similar discrepancies from Dirac theory were found in various lines of the helium spectrum, confirming theoretical explanations of the hydrogen anomaly (43).

The theoretical explanation of this anomalous level shift was sought in a more careful discussion of the Dirac theory itself, especially in the evaluation of the interaction of the electron with the radiation field. It has been found possible to separate from the infinite term which, in the expression for the total energy, gives the electromagnetic mass of the electron, a finite term which provides just the shift in energy levels observed by Lamb and Retherford (44).

Spectroscopic evidence has been accumulating which indicates that the Landé g-factors (which give the separation of fine-structure spectral lines) do not have the exact values predicted by current theory (45). In fact, this evidence indicates that, in addition to its ordinary magnetic moment of one Bohr magneton, the electron possesses a small intrinsic magnetic moment in magnitude about one thousandth of a Bohr magneton (46), although some have attempted to explain the anomalous g-values by a mass-defect of the electron (47). Theoretical calculations employing the latest theories of quantum electrodynamics are found to predict an intrinsic magnetic moment for the electron in agreement with experiment, and, what is more, these computations at the same time explain the hyperfine-structure anomalies and the Lamb-Retherford shift (48).

c. Quantum Electrodynamics

The impetus towards a development of a better theory of electrodynamics seems to have come principally from the necessity of overcoming the difficulty concerning the self-energy of fundamental particles; previous calculations gave infinity for the value of this energy, which corresponds to the rest-mass of the particle. One study attempts to remove the difficulty by the introduction of a fundamental length into the theories (49). The most important trend of present-day theory, however, is concerned with the formulation of a theory that will satisfy relativistic requirements, and with the identification of the various terms in the resulting expressions (50). These theo-

retical studies usually include specific practical applications with the view directed toward explaining the anomalous effects mentioned in the preceding section; they are analogously related to the advanced meson theories, to be related below, which developed out of them. This is the chief reason for mentioning them in a survey of nuclear physics.

3. Field (Meson) Theories

a. Meson Theories of Nuclear Forces

Many of the more general papers on meson theories employ the methods of advanced quantum electrodynamics currently under development, for both are field theories, analogous mathematically one to the other. In many of these meson investigations, too, the central problem is the formulation of the theory in such a way as to eliminate the divergences, the infinite values predicted for measurable quantities (51). Other contributions concern the various special types of meson theories and discuss the interactions of nucleons in the light of such theories (52). One difficulty, appearing in comparisons with experiment, has been that the mass of the meson required by theory is much greater than that observed in cosmic rays, 300 rather than 200 electron-masses. There is also some discussion of the suggestion that the divergence difficulties can be removed by adding a new interaction term to the Hamiltonian (total energy expression) of two protons; this suggestion does not seem to be a satisfactory solution of the problem (53).

Applications of meson theories to more specific problems include the computation of the magnetic moments of nucleons (protons or neutrons), by employing the procedures developed in quantum electrodynamics for circumventing the divergence difficulties (54), and the investigation of the magnetic moments of light composite nuclei in the light of the phenomenon of charge exchange between nucleons (55).

b. Properties of Mesons

An adequate treatment of all the research that has a proximate bearing on the present knowledge of mesons would include practically all that is published on cosmic radiation; without going too far into this interesting field it will, perhaps, suffice to indicate some major trends in those studies of mesons that have meaning for nuclear physics (56). One of the observable properties of mesons is their very short life-time, about 2 microseconds; by far the majority of papers dealing with mesons treats of their decay or capture in matter (57). Positive and negative mesons seem to have different properties: in some materials only positive mesons appear to decay, while in others decay electrons come from mesons of both signs. It seems that negative mesons can be captured into interior electron-like orbits, and thence even into the nucleus itself, very much faster than they would decay in atom-free space; thus, the disappearance of negative mesons

is due to a combination of natural radioactive decay and nuclear absorption, while positive mesons disappear only by decay. Another property of mesons, which is at least of equal interest from the viewpoint of nuclear physics, is their mass or masses. Treated in a number of papers are observations and theoretical explanations of cosmic ray phenomena in terms of light and heavy mesons, of neutral mesons and charged ones of both signs (58). Whereas the earliest mass measurements indicated the existence only of mesons with a mass equal to about 200 electron-masses ("μ-meson"), at least one other type clearly exists: those of mass equal to that of about 300 electrons ("π-meson"). The proof of the existence of a meson of mass 300 electron-masses was received with some relief by theoreticians; it was the existence of just such a meson that, before any such particles were experimentally observed, was postulated to explain nuclear forces. There seems to be a genetic relation between the heavy and the light types, the former decaying into the latter. The energy spectrum of mesons and their occurrence in "stars," nuclear evaporations recorded in photographic film at very high altitudes, are also topics of discussion (59). The process of the decay of mesons, besides being in itself interesting, has value also in that it leads to a knowledge of the reverse process, that of the production of mesons (60). Although other mechanisms are mentioned, that of nuclear collisions or bombardments is the most frequently discussed mode of production; this is a natural development now that giant accelerating machines, capable of producing the requisite high-energy projectiles, are in existence. Akin to these studies are a few on the analogous, extremely high-energy processes which may lead to the production even of neutrons or protons themselves. Perhaps the presence of such heavy particles in primary cosmic radiation may be accounted for by such a high-energy bombardment or similar process (61).

Conclusion

Due to the unavoidable span of time elapsed between the writing of a series such as this and its last appearance, its latest articles are already more than a year old. Fortunately the general character of present-day nuclear research has not changed much in the interval; perhaps the best way to conclude the series is by indicating briefly what has occupied nuclear physicists during 1949, as evidenced by papers published in the *Physical Review*.

Studies of fission-fragments and of the evidence for ternary fission keep nuclear fission a current topic. Radioactivity still maintains its status as the most popular subdivision, with all manner of investigations on energies, level-schemes, new radioactive isotopes, etc. The minimum observable life-time for isomeric transitions has been shortened considerably, and search made for isotopes with this type of gamma-radiation. The usual bombardment experiments have been continued, notably in the field of low-mass isotopes, including H^3 and

He^3. The new giant accelerators have caused fission and spallation (cleavage and chipping) of many different target nuclei, and have produced artificial mesons and artificial stars, both observed hitherto only in cosmic radiation.

There have been studies on bombardment resonances and energy levels, and rather a large number on magnetic moments, especially by microwave spectroscopy. The strange properties of the helium isotopes are gradually being untangled. The systematization of nuclear properties has proceeded chiefly by the correlation of the many natural and artificial alpha-emitters, and by the determination of the "magic-numbers" of neutrons and protons that give particularly stable isotopes.

The possibility of polarized projectiles and targets for nuclear bombardments, of special interest for determining the spin character of nuclear forces between simple particles, has been the subject of several papers. Neutron-proton scattering at 90 million electron-volt energies has been continued. Pursuit of the advances in quantum electrodynamics and radiation theories, as well as in the various forms of general meson theories, has been carried on by a larger number of investigators. The experimental work on cosmic rays is, if anything, more popular, with the character of this radiation being more accurately delineated now that artificial stars and mesons have been produced. Other significant topics in cosmic-ray research are the use of the V-2 rocket as an instrument for high-altitude studies, the directional properties of cosmic radiation, and the new, 900 electron-mass τ-meson.

(Concluded)

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Note. Since all the papers referred to appeared in the *Physical Review* for the years 1947 and 1948, reference will be made by indicating only the volume and page.

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(2) *73*, 16.
(3) *74*, 1730(L).
(4) *74*, 1194(L), 1876(L).
(5) *71*, 739(L).
(6) *71*, 126(L), 458(L).
(7) *73*, 803(L); *74*, 505(L), 1198(L), 1577, 1737, 1882(L).
(8) *73*, 79(L), 79(L).
(9) *71*, 379(L), 742(L); *72*, 435(L).
(10) *71*, 20, 736(L); *72*, 207; *73*, 197; *74*, 364.
(11) *72*, 1147; *73*, 262(L).
(12) *72*, 1258(L); *73*, 1114(L).
(13) *71*, 339, 384(L), 560(L); *72*, 1131; *74*, 553.
(14) *71*, 20.
(15) *72*, 662.
(16) *72*, 466; *74*, 48, 87, 1763.
(17) *71*, 215, 232; *72*, 576.
(18) *73*, 520(L), 1117(L), 1407(L).
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(20) *71*, 678.
(21) *72*, 355(L); *73*, 191, 641(L), 1411(L), 934, 973, 1132(L), 1403(L), 1409(L).
(22) *72*, 250(L), 731(L), 731(L); *73*, 1290.
(23) *73*, 869; *74*, 1546(L).
(24) *71*, 558(L), 829(L), 908(L)
(25) *73*, 1, 260(L).
(26) *73*, 986; *74*, 809.
(27) Cf. THIS BULLETIN, 27, 30, references 55-57.
(28) *74*, 1552(L), 1871(L).
(29) *73*, 184(L); *74*, 145, 699(L), 1885(L).
(30) *73*, 185(L); *74*, 1799.

(31) *71*, 457(L); *72*, 312; *73*, 185-(L); 919(L); *74*, 433, 1320.

(32) *72*, 749, 1017.

(33) *74*, 832(L), 833(L), 834(L).

(34) *72*, 634, 1139, 1254(L); *73*, 268(L).

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(36) *72*, 445.

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(39) *72*, 1253(L)

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(41) *71*, 914(L); *72*, 971(L); *73*, 718.

(42) *72*, 245(L); 1023; *73*, 808(L), 1109.

(43) *72*, 241, 972(L); *73*, 639(L); *74*, 219(L).

(44) *72*. 339; *73*, 173, 177(L), 630-(L), 617, 641(L); *74*, 224(L), 1278.

(45) *72*, 1256(L); *73*, 412(L), 1130(L); *74*, 250.

(46) *72*, 984(L); *73*, 1410(L); *74*, 656.

(47) *74*, 113(L), 844(L).

(48) *73*, 416(L); *74*, 893, 1157.

(49) *72*, 298, 1253(L).

(50) *72*, 628; *74*, 738, 950, 1070, 1430, 1439, 1485, 1789.

(51) *73*, 26, 519(L); *74*, 748, 985-(L), 1545(L).

(52) *71*, 908(L); *72*, 125, 219, 1126(L); *73*, 929(L); *74*, 538, 1864.

(53) *71*, 447; *72*, 225.

(54) *74*, 218(L), 986(L), 986(L), 1884(L).

(55) *72*, 256(L); *73*, 924(L); *74*, 500(L).

(56) For further references concerning mesons in cosmic radiation, cf. Volume Indices, *71-74*, under "Cosmic Radiation," especially the subdivisions, "Bursts," "Penetrating Particles," and "Stars."

(57) *71*, 209(L), 557(L), 314, 319 (L), 320(L), 550(L); *72*, 246(L), 248(L), 255(L), 399, 415, *772*; *73*, 81(L), 177(L), 257(L), 411(L), 565, 921(L), 1122(L), 1140, 1205(L), 1408(L); *74*, 101(L), 111(L), 349(L), 490(L), 492(L), 500-(L), 509(L), 697(L), 713, 850(L), 878, 1337, 1364, 1545(L), 1547(L), 1720, 1754.

(58) *71*, 387; *72*, 357, 360, 506, 724; *73*, 521(L), 521(L), 1122(L), 1128(L); *74*, 706-(L), 707(L), 1300, 1722(L), 1729(L).

(59) *72*, 120, 1054; *73*, 189(L), 1396(L); *74*, 38.

(60) *71*, 82; *72*, 1, 251(L), 266, 510(L), 734(L), 735(L); *73*, 127, 1128(L); *74*, 975(L).

(61) *71*, 842; *72*, 203, 254(L), 512(L), 513(L); *73*, 923, 1010, 1133(L); *74*, 97(L), 213, 226(L), 341, 504(L), 845(L), 1818, 1828, 1867, 1878(L).

News Items

"Magnopere juverit crebo alios de aliis certeriores fieri, ac audire quae ex variis locis ad aedificationem et eorum quae geruntur cognitionem afferuntur."— Const. VIII., I.

COLLEGE OF THE HOLY CROSS

DEPARTMENT OF MATHEMATICS. William F. Reynolds, '50, placed among the ten top contestants in the William Lowell Putnam Mathematical Competition for 1949. The competition is conducted annually by the Mathematical Association of America for the purpose of finding promising students of mathematics in the United States

and Canada. Mr. Reynolds was the only representative of a Catholic college to rank among the winners. He received both a cash award and a medal. Mr. Reynolds is a graduate of Boston Latin School and is a resident of Dorchester, Mass.

V. O. McBrien, Assistant Professor of Mathematics, is a co-author of a paper, "Basic Configurations of the Plane under Certain Groups" which appears in the October issue of *The Mathematics Magazine*.

FAIRFIELD UNIVERSITY

Department of Chemistry. Work is under way for furnishing and equipping our organic laboratory. It is expected that the new laboratory will contain approximately 150 lockers, with space for approximately 35 students per session.

The department recently announced the inauguration of a course leading to the B.S. degree in Chemistry, beginning with the fall semester 1950.

This year we have about 130 students enrolled in chemistry courses divided among the Freshman inorganic chemistry, Sophomore analysis and Junior elective courses.

FORDHAM UNIVERSITY

Fr. Steele has been delivering a series of lectures on mathematics to the Fordhamath Society. He also addressed the College's Archbishop Hughes' Gaelic Society on February 3 on "The Irish Contribution to Mathematics."

WESTON COLLEGE REQUESTS CHEMICAL JOURNALS

During the past year rather extensive work has been done in completing the periodical section of the Chemistry Library. This work has been undertaken for the benefit of the returning Theologians and the philosophers currently in Chemistry. We now have excellent sets of the *Chemical Abstracts, Journal of the American Chemical Society, Industrial and Engineering Chemistry, Analytical Chemistry* and the *Journal of Chemical Education*. The work would have been virtually impossible without the aid of several generous gifts. The house library has had these periodicals bound. A rather large collection of our duplicates of these periodicals was shipped to Father Guay in Baghdad last Summer.

At present we are interested in augmenting our set of *Chemical Reviews*. We have only twelve complete volumes of early Reviews. Any duplicates of volumes eighteen to date which you may have would be most gratefully received by us. We could also use any decennial index of the *Chemical Abstracts* and any other periodicals which you may consider a useful addition to our library. In return, some of our duplicates might fit into your file.